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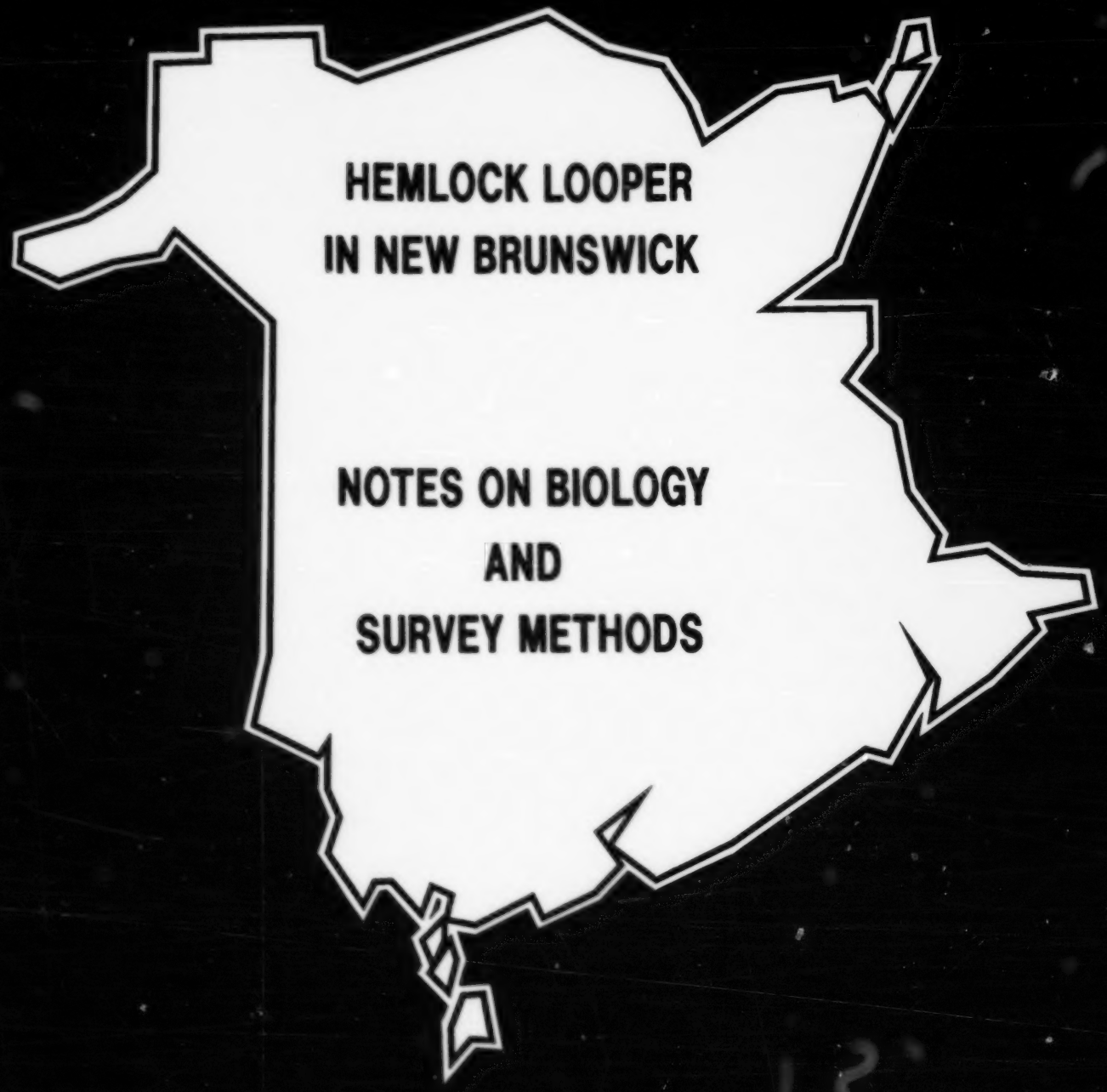

HEMLOCK LOOPER IN NEW BRUNSWICK

NOTES ON BIOLOGY AND SURVEY METHODS

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HEMLOCK LOOPER IN NEW BRUNSWICK: NOTES ON BIOLOGY AND SURVEY METHODS

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ABSTRACT

The eastern hemlock looper had not previously been a pest of concern in the forests of New Brunswick and hence local information was unavailable when damage by this insect was first noted in 1989. Forecasting methods developed in Newfoundland were adopted for use in 1989 leading to New Brunswick's first-ever spray program against hemlock looper in 1990. This report presents biological information and survey methods based on various actions taken in 1989 and 1990.

Collections of larvae and subsequent head capsule measurements confirmed that there are five larval instars in this Province. Color and marking characteristics of first and second instar larvae are described. Larval development appeared to be closely related to degree-day accumulations above 3°C commencing April 1st.

Parasitism of hemlock looper pupae appeared to be 19% and 16% in 1989 and 1990, respectively. Nine species of parasitic wasps accounted for 100% and 76% of parasitism in respective years. In 1990, the balance of pupal parasites were tachinid and sarcophagid flies.

Egg parasitism was negligible in 1989. It was higher in 1990, with 21% of the plots having some level of parasitism, ranging from 1-5% to 91-100%. Much of the parasitism was due to an unidentified parasite already emerged from the looper eggs at time of sampling. This relationship requires further investigation. Other parasites reared from looper eggs were Trichogramma minutum Riley and Trichogramma sp.

For forecasting purposes, eggs were extracted from a 100-cm lower-crown branch from each of 5 balsam fir trees per plot. Data analysis revealed that one branch from each of 3 trees was as valid as 5 ($r^2 = 0.94$) or 10 ($r^2 = 0.92$) trees.

The number of eggs on sections of 100-cm branches were compared to the total number of eggs on the branch in a number of plots. The strongest relationship was with the 46 to 100-cm basal section ($r^2 = 0.98$) followed by the 76 to 100-cm basal section ($r^2 = 0.95$). The relationship was next strongest with the distal 75-cm tip ($r^2 = 0.71$), and was weakest with the distal 45-cm tip ($r^2 = 0.51$). These relationships need replication and verification as they apply to 1989 data only.

A good relationship between fall/winter egg counts and spring larval counts was obtained when larval counts were expressed "per 100-cm branch" ($r^2 = 0.72$) and "per square metre of foliage" ($r^2 = 0.76$). Data relating egg counts to subsequent tree damage were only available for samples with fewer than 10 eggs/100-cm branch because all plots with higher values were treated in 1990. Counts of fewer than 10 eggs/100-cm branch caused less than 10% loss of current year needles and less than 17% needle loss for all age classes combined. More data are needed to develop predictive relationships between eggs and damage.

An extraction process using household bleach was used to remove looper eggs attached to branch samples. This system, developed by Forestry Canada in Newfoundland, is now used operationally in New Brunswick. The extraction procedure is described in this report.

ACKNOWLEDGEMENTS

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Species identifications of the hemlock looper parasites were made by Ms. Georgette Smith (Forestry Canada - Maritimes) and the Biosystematics Institute of Agriculture Canada. Dr. Eldon Eveleigh (Forestry Canada - Maritimes) examined the 1989 pupae for diseases. Their contributions are gratefully acknowledged.

Mr. Breck Alward, a summer employee with the Forest Pest Management Section is acknowledged for providing the analysis and graph of hemlock looper head capsule widths used to determine larval instars. Mr. Alward was given permission to present this data in an undergraduate forestry thesis (Alward, 1990) at the University of New Brunswick.

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TABLE OF CONTENTS

	Page
ABSTRACT	i
ACKNOWLEDGEMENTS	ii
LIST OF TABLES	iv
LIST OF FIGURES	v
1. BACKGROUND	1
2. LARVAL DEVELOPMENT	
2.1 Determination of larval instars	2
2.2 Larval development vs accumulated degree-days	4
3. PUPAL AND EGG PARASITES	
3.1 Pupal parasites	6
3.2 Egg parasites	9
4. FORECAST SURVEY METHODS	
4.1 Sample size per plot	13
4.2 Egg distribution within the branch	15
4.3 Egg counts as a predictor of defoliation by hemlock looper	17
4.4 Egg survey as a predictor of larval populations	17
SUMMARY	19
REFERENCES	20
APPENDIX A - Study locations reported in text	22
APPENDIX B - Hemlock looper egg extraction process as used in New Brunswick	24

LIST OF TABLES

		Page
Table 1.	Head capsule measurements for hemlock looper larvae collected in the summer of 1990 in north-central New Brunswick.	2
Table 2.	Percent hemlock looper moth emergence and mortality factors affecting pupae, 1989 and 1990.	7
Table 3.	Species of parasites emerging from hemlock looper pupae reared in 1989 and 1990.	8
Table 4.	Parasitism of hemlock looper eggs in 1989 and 1990.	9
Table 5.	Parasitism of hemlock looper eggs over time at a plot on Sweat Hill in the Christmas Mountains area of northern New Brunswick.	11
Table 6.	Parasitism rates in plots having hemlock looper eggs in 1990.	12

LIST OF FIGURES

		Page
Figure 1.	Frequency of head capsule measurements (n=626) for hemlock looper larval instars in New Brunswick.	3
Figure 2.	Scatter diagram of hemlock looper larval development index versus accumulated degree-days from April 1 to July 31, 1990 (threshold of 3°C) (from Hartling and Carter, 1991).	5
Figure 3.	Regressions of hemlock looper mean egg counts per 100-cm branch for three vs five branches (A) and three vs ten branches (B).	14
Figure 4.	Regressions of hemlock looper egg counts per 100-cm branch vs sub-sections of the 100-cm branch.	16
Figure 5.	Regressions of fall egg counts vs subsequent spring larval counts (L1-L3).	18
Figure A-1	Locations where hemlock looper was sampled in 1989-90.	23

HEMLOCK LOOPER IN NEW BRUNSWICK: NOTES ON BIOLOGY AND SURVEY METHODS

1. BACKGROUND

In 1989, an eastern hemlock looper (Lambdina fiscellaria fiscellaria (Gn.)) outbreak causing severe damage to balsam fir was detected in north-central New Brunswick. This was the first outbreak recorded for New Brunswick (Magasi, 1990). An aerial survey of defoliation was jointly conducted by provincial and federal forestry staff who mapped 3 817 ha of defoliation (Hartling and Carter, 1991).

The Department of Natural Resources and Energy (DNRE) conducted an egg survey in the fall of 1989 at 128 plots in northern and southern New Brunswick. Based on results from this survey an area of 20 000 ha in northern New Brunswick was delineated as containing populations expected to be great enough to cause significant feeding damage in 1990 (Hartling and Carter, 1991). Subsequently, an area of 21 160 ha encompassing the entire forecast area was treated with insecticide in 1990. Details of this first-ever spray program against hemlock looper in New Brunswick are reported in Hartling and Carter (1991).

An aerial survey of defoliation was conducted in the summer of 1990. An area of 3 477 ha was mapped as having hemlock looper defoliation, of which 78% included spruce budworm defoliation (Hartling and Carter, 1991).

Another egg survey was conducted in the fall of 1990 at 231 plots in northern and southern New Brunswick. Information from the 1990 defoliation map and egg survey were combined and used to delineate an area of 22 692 ha in which pockets of defoliation were expected to occur in northern New Brunswick in 1991 (Hartling and Carter, 1991). In addition, an area of about 6 771 ha in southwestern New Brunswick was forecast to have pockets of defoliation in 1991. An area of 16 975 ha in northern New Brunswick was treated with a single application of bacterial insecticide (Bacillus thuringiensis) in 1991 (Davies, 1991).

From various sites located around the Province (Appendix A), DNRE has amassed data on the biology of hemlock looper which have not been previously reported from New Brunswick. As well, population survey methodology has been evaluated. Although the data were not collected by way of rigorous scientific experimentation, this information may interest researchers as well as foresters and entomologists responsible for conducting "operational" looper surveys and control programs.

This report is divided into three sections, based on larval development, pupal and egg parasites, and egg surveys as a method of forecasting.

General information on the biology and behavior of the insect are not discussed. An excellent overview of hemlock looper can be found in Martineau (1984).

2. LARVAL DEVELOPMENT

2.1 Determination of Larval Instars

This section deals with the number of larval instars present in New Brunswick and measurements of head capsule widths for each instar. This information is important for timing and assessing spray programs. The literature reports five larval instars in Ontario (de Gryse and Schedl, 1934) and only four larval instars in Newfoundland (Carroll, 1956; West et al., 1987). Information reported here is the only known data of head capsule measurements specific to New Brunswick.

Larvae were collected from branch samples throughout the summer of 1990. Analysis of head capsule widths of 626 larvae disclosed five discrete intervals (Table 1), indicating that in New Brunswick there are five larval instars (Figure 1). These head capsule ranges were partially tested in 1991 using field-collected specimens from both northern and southern New Brunswick. After measuring over 5000 insects, primarily 1st to 3rd instar larvae, it was found that less than 1% fell outside the described ranges.

Table 1. Head capsule measurements for hemlock looper larvae collected in the summer of 1990 in north-central New Brunswick.

Larval Instar	Number Measured	Range (mm)	Mean (mm)	Standard Deviation (mm)
I	100	0.30-0.45	0.38	0.02
II	216	0.50-0.75	0.63	0.03
III	140	0.85-1.15	0.94	0.06
IV	71	1.20-1.55	1.37	0.06
V	99	1.75-2.20	1.96	0.09

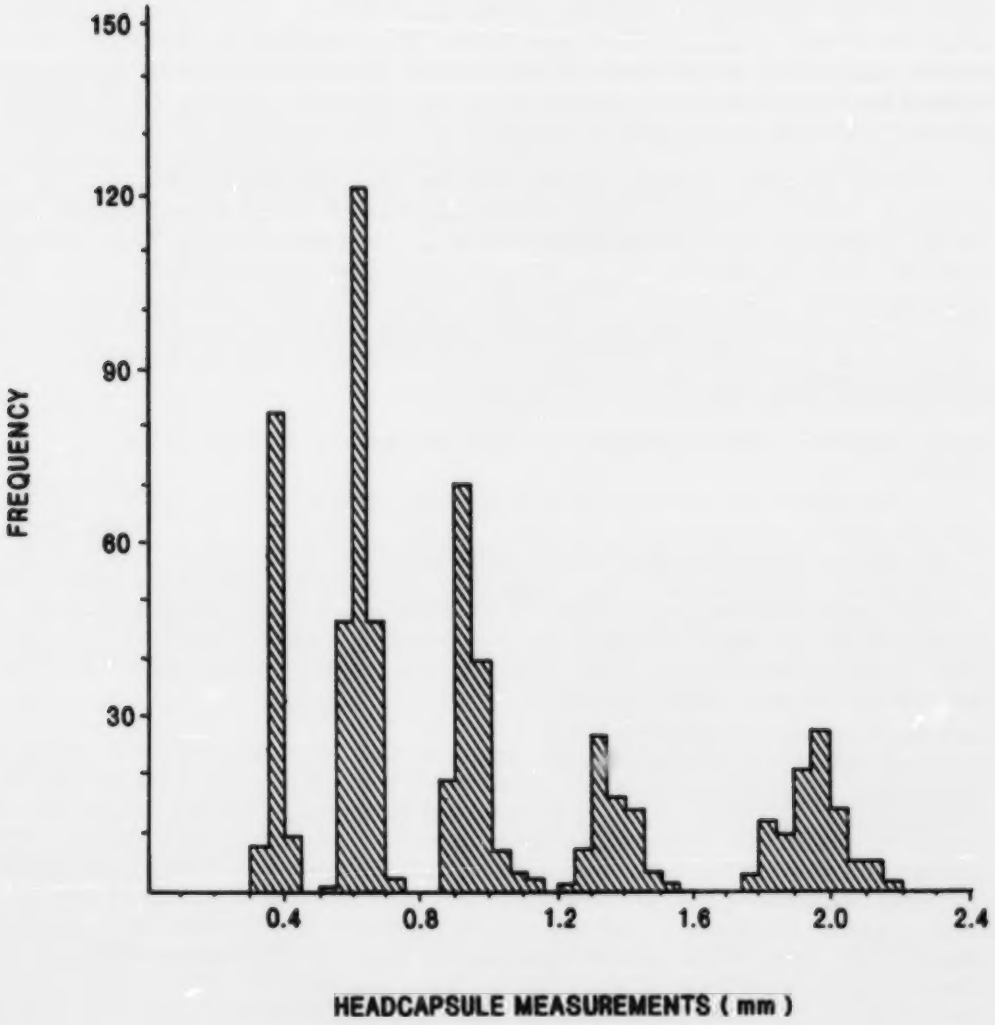

Figure 1. Frequency of head capsule measurements (n=626) for hemlock looper larval instars in New Brunswick.

Biological information used to determine the appropriate time to apply the first spray application in 1990 and 1991 was based on the proportion of first and second larval instars (eg. Hartling and Carter, 1991). Making daily head capsule measurements on a large number of larvae is quite time consuming, therefore several color and marking characteristics were identified as helpful features to more quickly separate first and second larval instars. This enables field technicians to only double check with head capsule measurements on a small subset of the larvae collected.

The first instar larva can be easily identified by a dark head capsule and a broad dark brown or black band encircling each white body segment. In contrast, the head capsule of the second instar larva has a white and brown mottled appearance and the bands encircling the body segments are not as pronounced. Bands or striping encircling the first instar are quite visible to the naked eye. A microscope, however, is needed to see the coloration of the head capsule for both instars.

2.2 Larval Development vs Accumulated Degree-Days

As part of the spruce budworm operational spray program, DNRE calculates degree-day accumulations above 3°C commencing April 1 from many weather stations around the Province. This provides a relative indicator of spruce budworm larval development at locations throughout the Province. Since temperature data are available in this format on an annual basis, it was decided to use the same threshold for comparing degree-day accumulations with hemlock looper development.

A scatter diagram of degree-day accumulations versus looper larval development index[1] indicated a good relationship using this threshold (Figure 2). It would be appropriate, however, to add a word of caution regarding interpretation of these data. The eleven data points from southwestern New Brunswick represent degree-day accumulations from a weather station at Milltown, 7 to 19 km from the plots in which larval development information was collected. Each of the two data points from southeastern New Brunswick represent weather data from two separate stations (Sussex and Moncton), 20 and 30 km from the larval plots. In all these cases, topographic (i.e. altitude) and climatic conditions were similar between the weather stations and associated plots monitored for larval development. However, in northern New Brunswick, larval development was compared with a weather station at Nictau located in a valley, 32 to 39 km from the plots in spray blocks H and P, respectively. These blocks are situated at much higher elevation than the Nictau weather station. Furthermore, larval index in these blocks may have been altered due to larval mortality after several applications of insecticide after 506 degree-days.

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1. Larval Index = [(No. L1) x 1 + (No. L2) x 2 ... + (No. L5) x 5] ÷ Total No. Larvae.

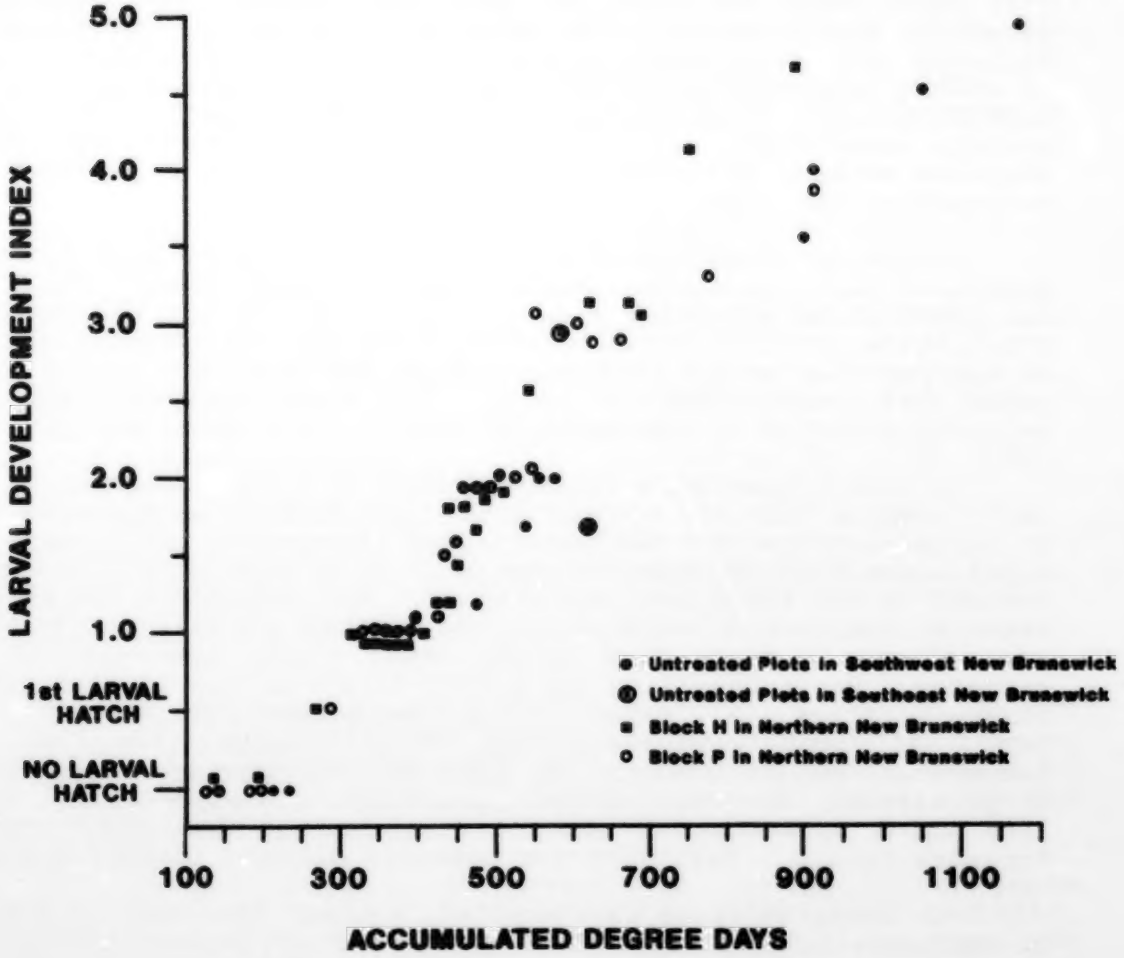

Figure 2. Scatter diagram of hemlock looper larval development index versus accumulated degree-days from April 1 to July 31, 1990 (threshold of 3°C) (from Hartling and Carter, 1991).

3. PUPAL AND EGG PARASITES

3.1 Pupal Parasites

Pupae were collected in 1989 and 1990 at two geographic locations approximately 15 km apart in north-central New Brunswick (Appendix A). Both locations were treated with insecticide in 1990 to reduce expected levels of looper feeding damage (Hartling and Carter, 1991). Pupal collections were made as part of the spray program assessment, as well as to estimate parasitism rates. Sampling methods differed between years to reflect the needs and purposes at the time.

Following cessation of feeding, larvae descend host trees in search of pupation sites. Studies indicate most insects pupate on the tree but occasionally pupation occurs on the ground (Carroll, 1956; Otvos, 1974). Carroll (1956) found that in Newfoundland 90% of the pupation on the tree occurred on the stem, and 62% of those pupae were found below the crown. For these reasons, the tree bole was selected as the sampling zone.

In 1989, pupae were collected from 60 trees on August 21 and 22. Flagging tape was wrapped around the bole of each sample tree at heights of one and two metres from the ground. All pupae and pupal cases found between the two bands were counted, and the pupae brought to the laboratory for rearing. Moth emergence had already begun at the time of collection. One hundred and fifty-seven pupae were placed in mason jars having small screen openings for air exchange. Paper towelling was placed in the bottom of each jar to absorb moisture. All pupae from a single tree were placed in one jar. All pupae were placed in jars on August 23, kept at room temperature and periodically checked for emergence of looper adults or parasites. The rearing was terminated on September 23. Pupae from which parasites or moths did not emerge were submitted to Forestry Canada - Maritimes for possible disease identification.

In 1990, 40 trees were sampled, 4 trees from each of 5 plots at two sampling locations. Rather than collect pupae directly from the bole of trees, burlap traps were used (Otvos, 1974). A piece of burlap was wrapped around the tree at breast height, allowing for some overlap. The top was stapled to the tree and the bottom folded up and stapled in place in such a way as to leave gaps between the two layers of burlap. The height of the traps was 38 cm. Moss and forest litter were stuffed between the two layers to provide pupation sites for looper larvae descending the trees. Traps were put in place from July 23 to 25, collected on August 14 and 15, and transported to the laboratory. Two hundred and thirty-eight pupae were placed individually in labelled 8 dram vials, with openings plugged with cotton batten. All pupae were kept at room temperature, checked periodically for emergence of moths and parasites, and rearing terminated in January, 1991. It was found that all parasites had emerged by October, 1990.

Representative parasite specimens were submitted to the Forest Insect and Disease Survey of Forestry Canada - Maritimes for identification. These same parasites were then forwarded to Biosystematics Research Center in Ottawa (Agriculture Canada) for confirmation.

Parasitism rates were 19% and 16% for 1989 and 1990, respectively (Table 2). In 1989, 49% of the looper moths had already emerged at time of collection (August 21 and 22). All empty pupal cases were recorded as "emerged moths". In 1990, all pupae were collected (August 14 and 15) prior to any emergence of moths.

Table 2. Percent hemlock looper moth emergence and mortality factors affecting pupae, 1989 and 1990.

Categories	% Pupae (No. Pupae)			
	1989		1990	
Moth Emergence	64%	(208)	46%	(109)
No Moth Emergence				
Parasitized	19%	(62)	16%	(38)
Disease	12%	(41)	}	
Dead of Unknown Causes	4%	(13)	}38%	(91)
Preyed Upon	1%	(3)	}	
Totals	100%	(327)	100%	(238)

Based on moth emergence in 1990 (n=109), the sex ratio was 57% female and 43% male. This compares closely to the 55:45 female: male ratio reported in Newfoundland by Carroll (1956), based on 1000 adults reared from field-collected larvae and pupae. The sex ratio was not determined in 1989.

Disease was found to be present in 12% of looper pupae collected in 1989 (Table 2). Diseased pupae harboured bacteria, and/or fungi. It was not possible to determine if these organisms were the primary cause of death, or merely opportunistic species which invaded the pupae after mortality occurred (E. Eveleigh, pers.comm., 1990)[1].

The majority of parasites emerging from pupae were Hymenoptera (Table 3), 100% in 1989 and 76% in 1990; the remaining parasitized pupae had tachinid and sarcophagid flies emerge in 1990. Although there were nine species of parasitic wasps, most belonged to the taxonomic family Ichneumonidae. A single species, Itoplectis conquisitor (Say) issued from 49% to 59% of the parasitized pupae.

1. Forestry Canada - Maritimes, Fredericton, N.B.

Table 3. Species of parasites from hemlock looper pupae reared in 1989 and 1990[1].

Taxonomic Group - Order (Family)	Species	Parasitized Pupae 1989 n	(%)	1990 n	(%)
Hymenoptera (Ichneumonidae)	Itoplectis conquisitor (Say)	29	(59%)	18	(49%)
	Apechthis (Ephialtes) ontario (Cresson)	9	(18%)	-	
	Mastrus sp.	7	(14%)	-	
	Gelis sp.	2	(4%)	-	
	Aoplus velox (Cresson)	-		5	(14%)
	Pimpla pedalis (Cresson)	-		2	(5%)
	Dusona sp.	-		1	(3%)
(Pteromalidae)	Diabrachys cavus (Walker)	2	(4%)	-	
	Hymenoptera larvae, undetermined	-		2	(5%)
Diptera (Tachinidae)	Madremyia saundersii (Williston)	-		4	(11%)
and (Sarcophagidae)	Sarcophagid Larvae	-		5	(14%)
Totals		49	(100%)	37	(100%)

1. All parasites were collected as adults except where noted. Number of pupae parasitized does not equal that in Table 2 because some pupae were not kept for rearing; percentages do not add up to 100% due to rounding off.

Parasitic wasps of the family Pteromalidae issued from several looper pupae (Table 3). These insects lay numerous eggs in a single host (Swan and Papp, 1972). In 1989, two looper pupae were parasitized by the Pteromalid Diabrachys cavus (Wlk). D. cavus is known to be both a primary parasite (Swan and Papp, 1972) and a hyperparasite (Swan and Papp, 1972; Otvos, 1973). Ten parasites issued from these two pupae.

Parasitic wasps and flies which parasitized hemlock looper pupae were similar to those reported in Ontario by de Gryse and Schedl (1934) and to these found in Newfoundland (Carroll, 1956; Otvos, 1973). Many of those parasites have also been reported to parasitize spruce budworm (Miller, 1963; Tilles and Woodley, 1984), a pest of fir and spruce which has existed at infestation levels throughout northern New Brunswick for decades.

3.2 Egg Parasites

Egg parasitism was negligible in 1989. Of 3582 eggs extracted from 83 plots only 12 were parasitized (Table 4). However, the number of parasitized eggs found on a plot basis was not recorded hence it is uncertain whether the parasitized eggs came from several plots or one from each of the 12 plots.

Assessment of egg parasitism in 1990 was more complicated. Of 1882 eggs obtained from 133 plots, only 31 intact parasitized eggs were found. An additional 223 parasitized eggs, each with a hole from which the parsite(s) apparently issued, were found at 12% of the plots (n=16) (Table 4). No such parasitized eggs with exit holes were seen in 1989.

Table 4. Parasitism of hemlock looper eggs in 1989 and 1990.

Year	No. Sampled[1]		No. Plots Having Looper Eggs	No. Eggs Examined[2]	No. Eggs Parasitized	
	Plots	Trees			Parasite Inside Egg	Parasite Emerged
1989	128	650	83	3582	12	0
1990	229	1145	133	1882	31	223[3]

1. In most cases, 5 trees were sampled per plot. One 100-cm branch was removed from the lower crown of each sampled tree.

2. No. Eggs Examined = Viable + Parasitized (parasite inside egg) + Parasitized [with parasite(s) emerged].

3. Seventeen trees from 2 plots located within an outbreak first detected in 1989 had very high numbers of parasitized eggs from which parasites had emerged. Unfortunately, the actual number of eggs was not recorded; only after finding such high numbers were records kept for the remaining plots. Data from those two plots is therefore not included in the table.

Parasitized eggs were kept at room temperature in the laboratory until parasite emergence. Parasites which emerged from hemlock looper eggs layed in 1989 were identified as Trichogramma minutum Riley and Trichogramma sp. Parasites which emerged from looper eggs layed in 1990 were identified as T. minutum. An average of 3.6 parasite wasps (range 0-5) emerged from each looper egg parasitized in 1990. The median value was 4.

The genus Trichogramma has a wide range of host species, although the seasonal host sequences are not known (Anderson, 1976). T. minutum is a common egg parasite of the spruce budworm (Miller, 1963; Martineau, 1984), however, the sequence of alternate hosts of this budworm egg parasite is unknown (Neilson, 1963). Information reported here suggests that, in New Brunswick, the hemlock looper egg is an alternate host in which this parasite overwinters.

Telenomus dalmani (Ratz.) is the parasite frequently reported to attack hemlock looper eggs in Ontario (Carroll, 1956) and in Newfoundland (K. Pardy, pers. comm.,1991)[1]. Also reported from Newfoundland is Telenomus sp. (Otvos and Bryant, 1972; Otvos, 1973; K. Pardy[1], pers. comm., 1991). It is unclear whether Telenomus sp. is the same species as T. dalami. According to Anderson (1976), little is known about the biology of this genus, making valid species identification difficult.

The black eggs having exit holes are rather intriguing. Assuming they were parasitized eggs, we do not know the species of parasite or with certainty the generation of looper eggs from which they issued. Fortunately there were detailed egg counts made at ten plots in northern New Brunswick in the fall of 1989, spring 1990, and the fall of 1990. Black eggs with exit holes were not found at these plots in the fall of 1989 or the spring of 1990, but showed up in abundance in the fall of 1990. For example, data from the plot having the highest egg counts, and located within the outbreak first detected in 1989, are presented (Table 5). There are at least two possible hypotheses as to what occurred. First, the parasites layed their eggs in looper eggs in the fall of 1989, but parasite development did not affect looper embryo development to the extent of blackening the eggs until after the May (1990) sampling period. Parasite emergence then occurred after the larval hatch of hemlock looper, which began June 6. The second hypothesis, believed to be more plausible, is that parasites layed their eggs and emerged from host eggs in the fall of 1990, prior to the October 16 (1990) sampling period. This occurs for T. minutum on Zeiraphera canadensis Mut. & Free. (Ostaff, unpubl. data)[2], a lepidoptera defoliator which overwinters in the egg stage as does hemlock looper. If this occurred for hemlock looper, then the parasite would have either had to find another host in which to overwinter, or overwintered elsewhere outside a host. Anderson (1976) noted that some species of Telenomus (Scelionidae) and Ooencyrtus (Encyrtidae) do overwinter as adults in litter or loose bark. These two genera, along with Trichogramma(Trichogrammatidae) were considered by Anderson (1976) to be the most important egg parasites of forest defoliating Lepidoptera.

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1. Forestry Canada - Newfoundland and Labrador Region, St. John's, Nfld.
2. Forestry Canada - Maritimes, Fredericton, N.B.

Table 5. Parasitism of hemlock looper eggs over time at a plot on Sweat Hill in the Christmas Mountains area of northern New Brunswick.

Date Collected	Date Processed	No. Trees Sampled[1]	No. Eggs Counted: Healthy	Parasitized	Parasitized with Exit Hole
Oct. 17/89	Nov.22&23/89	5	300	0	0
May 16&17/90	May 20/90	5	540	14	0
Oct. 16/90	Nov. 5/90	10	26	2	130

1. One 100-cm lower crown branch sampled per tree. The trees sampled in Oct, 1989 and May, 1990 are different trees. The 10 trees sampled in Oct, 1990 were the same trees sampled in Oct, 1989 and May, 1990.

Telenomus sp. reported in Newfoundland is believed to overwinter in looper eggs (I. Otvos, pers. comm., 1991)[1], and T. dalmani in Ontario is reported to emerge in summer (Carroll, 1956). Experience from 1989 and 1990 suggests Trichogramma sp. and T. minutum overwinter in the blackened egg because cold treatment was used to get parasite emergence. However, this does not necessarily prove that Trichogramma actually needs cold treatment in order to emerge from looper eggs. It has been suggested that the mysterious parasite could be a species of Trichogramma which emerged in the fall from eggs laid early in the flight period of the looper moth and then searched for other eggs to parasitize, or died in the process (R. West, pers. comm., 1991)[2]. If the mysterous parasite is a fall emerging species, it remains to be seen whether it is Trichogramma or another species not reported in the scientific literature for eastern North America.

Making the assumption that the mysterious parasite is a fall emerging species which parasitized looper eggs layed in 1990, parasitism rates were calculated accordingly for each plot (Table 6). No parasitism was detected at 79% of the 133 plots at which looper eggs were found. The remaining 21% of these plots (n=28) had egg parasitism ranging from 1-5% to a high of 91-100%.

1. Forestry Canada - Pacific and Yukon Region, Victoria, B.C.
2. Forestry Canada - Newfoundland and Labrador Region, St. John's, Nfld.

Table 6. Parasitism rates in plots having hemlock looper eggs in 1990[1].

% Parasitism	No. Plots (% of Total)[2]	Number Eggs Assessed At Each Plot
0%	105 (79%)	X = 9.4, median = 4, range = 1-67
1-5%	3 (2%)	41, 81, 67
6-10%	5 (4%)	71, 54, 13, 17, 1
11-20%	3 (2%)	6, 7, 7
21-30%	3 (2%)	15, 52, 7
31-40%	2 (2%)	13, 9
41-50%	5 (4%)	2, 2, 2, 9, 4
51-60%	2 (2%)	5, 18
61-70%	3 (2%)	3, 12, 5
71-80%	0 (0%)	0
81-90%	1 (1%)	156
91-100%	1 (1%)	40
Total Plots =	133(100%)	

1. At two plots, parasitized eggs with exit holes were not counted. (Refer explanation in Table 4, footnote #3). Parasitism in those two plots was estimated to be >70%.

2. Percentages do not add up to 100% due to rounding off.

4. FORECAST SURVEY METHODS

The egg survey is used to predict damage expected to be caused by hemlock looper feeding in the following year. The distribution and severity of forecasted damage levels can be used to determine if susceptible forest stands need protection. This assumes there are known relationships between egg counts and subsequent damage. These relationships have never been established in New Brunswick. When planning the 1990 and 1991 spray programs (Hartling and Carter, 1991) DNRE relied on data from Newfoundland (Dobesberger, 1989; Clarke et al., 1990), and is now developing damage forecast curves specific to New Brunswick. Information presented in this section is based on data collected in 1989 and 1990.

Hemlock looper moths are active from August to mid-October in New Brunswick (unpublished data). The insect overwinters in the egg stage (Martineau, 1984). Eggs are layed singly or in groups of two or three on twigs, needles, and bark (de Gryse and Schedl, 1934), as well as on the forest floor (Otvos and Bryant, 1972). The tiny size of the eggs make them extremely difficult to find on branches. Otvos and Bryant (1972) developed a solvent extraction process using household bleach, to remove eggs attached to the branch substrate. This system is used operationally by Forestry Canada - Newfoundland and Labrador Region and has been adapted for use in New Brunswick (Appendix B). Processing each branch is a lengthy and costly procedure; it takes three lab technicians to process an average of fifty 100-cm branches per day (unpublished data).

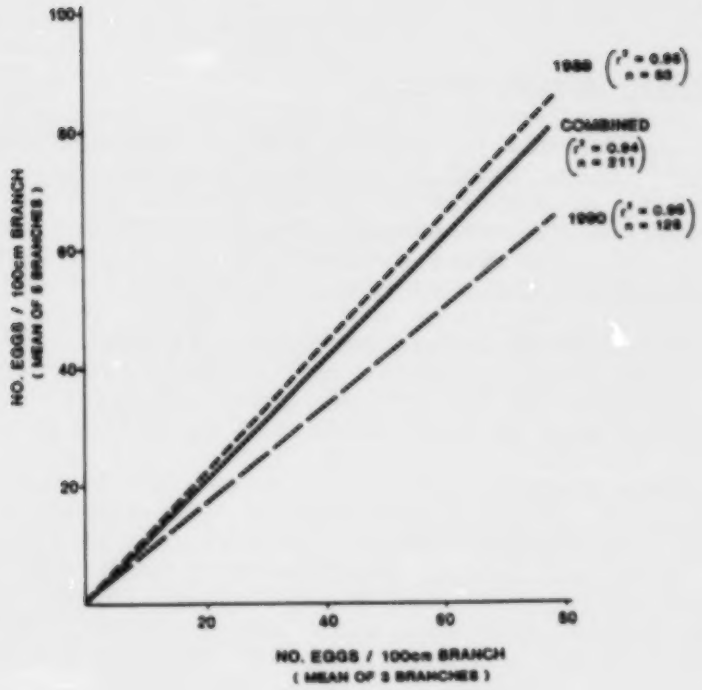
4.1 Sample Size Per Plot

One lower-crown 100-cm branch was removed from each of 5 fir trees per plot for operational surveys in 1989 and 1990. Branches were brought to a laboratory in Fredericton where the eggs were extracted.

The data were analyzed to determine if there was any significant difference in mean egg counts between sampling 5 branches or only 3 branches per plot. As well, a small subset of data for 10 branches per plot were compared to 3 branches per plot.

Regressions of average egg counts of three branches versus five branches were very strong based on 211 data points from both years ($r^2 = 0.94$) (Figure 3A). Similarly, regressions of average egg counts of three branches versus ten branches were very strong ($r^2 = 0.92$ for two years' data) (Figure 3B), although the data set was very limited (n=19). These regressions suggest that three branches are as representative a sample as five or ten branches. By using only 3 branches a 40% reduction in processing time could be realized. Field collection effort would only be slightly reduced since the time to drive to the site, and walk to the stand are major time costs. Whether mean egg counts from branches provide a reliable prediction of damage remains to be determined.

A



B

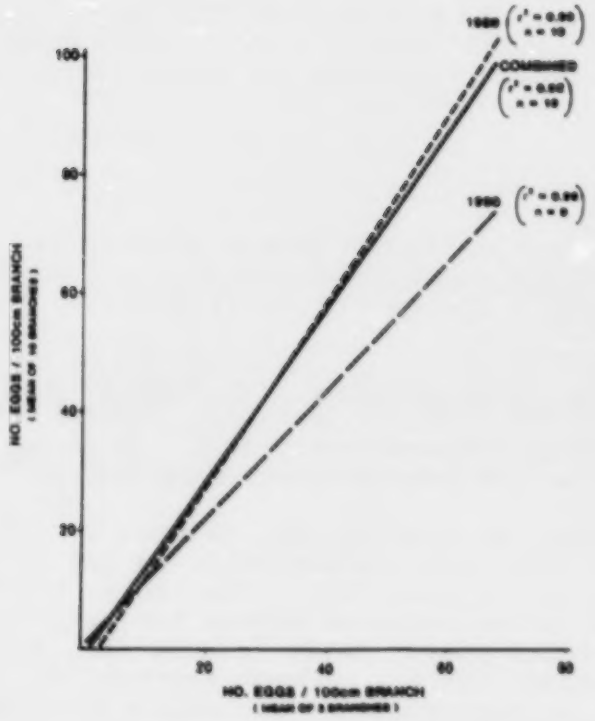


Figure 3. Regressions of hemlock looper mean egg counts per 100-cm branch for three vs five branches (A) and three vs ten branches (B).

4.2 Egg Distribution Within The Branch

An analysis of egg distribution on fir trees in Newfoundland found that the highest mean egg density occurred on bottom crown branches; however, no statistically significant difference was found between lower, middle, and upper crown branches (Dobesberger, 1989). After evaluating available information from reports and personal conversations with Newfoundland officials (eg. Dobesberger, October, 1989), it was decided to use a lower-crown branch, 100-cm in length as the sampling unit. Since hemlock looper female moths lay their eggs on lichen and in bark crevices on the branches and bole of the tree, as well as on the ground, it is important to realize that the 100-cm branch sample is only a relative indicator of population density, and ultimately of expected damage levels.

Extraction of eggs (Appendix B), while a straight forward procedure, is time consuming and costly. Factors such as branch size and condition (eg. past defoliation and age of tree) affect the amount of dirt and other debris that is removed from the branch along with the eggs. Debris affects the number of times the filtering process is repeated, and the number of filters that have to be examined. If a smaller length of branch could be used, then the time required to process a branch would be reduced, allowing more samples to be processed ir a given time.

A subset of fir branches (n=56) processed during the 1989 looper egg survey were cut in three sections and processed separately to examine egg distribution between sections of branch. The 100-cm branch was sectioned into a 45-cm tip, 46 to 75-cm mid-section, and 76 to 100-cm remaining basal section. The number of eggs on each section could then be combined to compare the whole branch (100-cm) with the 45-cm tip and with the 75-cm branch tip (i.e. 45-cm tip plus 46 to 75-cm mid-section). As well, the 46 to 100-cm branch section (i.e. 46 to 75-cm mid-section plus 76 to 100-cm basal section) and the 76 to 100-cm basal branch section were compared to the whole (100-cm) branch.

The 45-cm branch tip gave the poorest relationship ($r^2 = 0.51$) with the 100-cm whole branch (Figure 4). The 75-cm tip showed a good relationship ($r^2 = 0.71$) with the 100-cm whole branch (Figure 4). The strongest relationships existed for the 46 to 100-cm section ($r^2 = 0.98$) and the 76 to 100-cm section ($r^2 = 0.95$) when plotted against the 100-cm whole branch (Figure 4). Also noted was that the regressions of 46 to 100-cm branch section vs 100-cm whole branch approximated a 1:1 relationship. In other words very few eggs are layed on the 45-cm tip of the branch. Presumably there are more egg-laying sites further back on the branch than at the tip. These data suggest that a 100-cm branch could be cut and the 45-cm tip discarded, thus saving considerable processing costs. It is cautioned that these are data for one year only, and should be replicated.

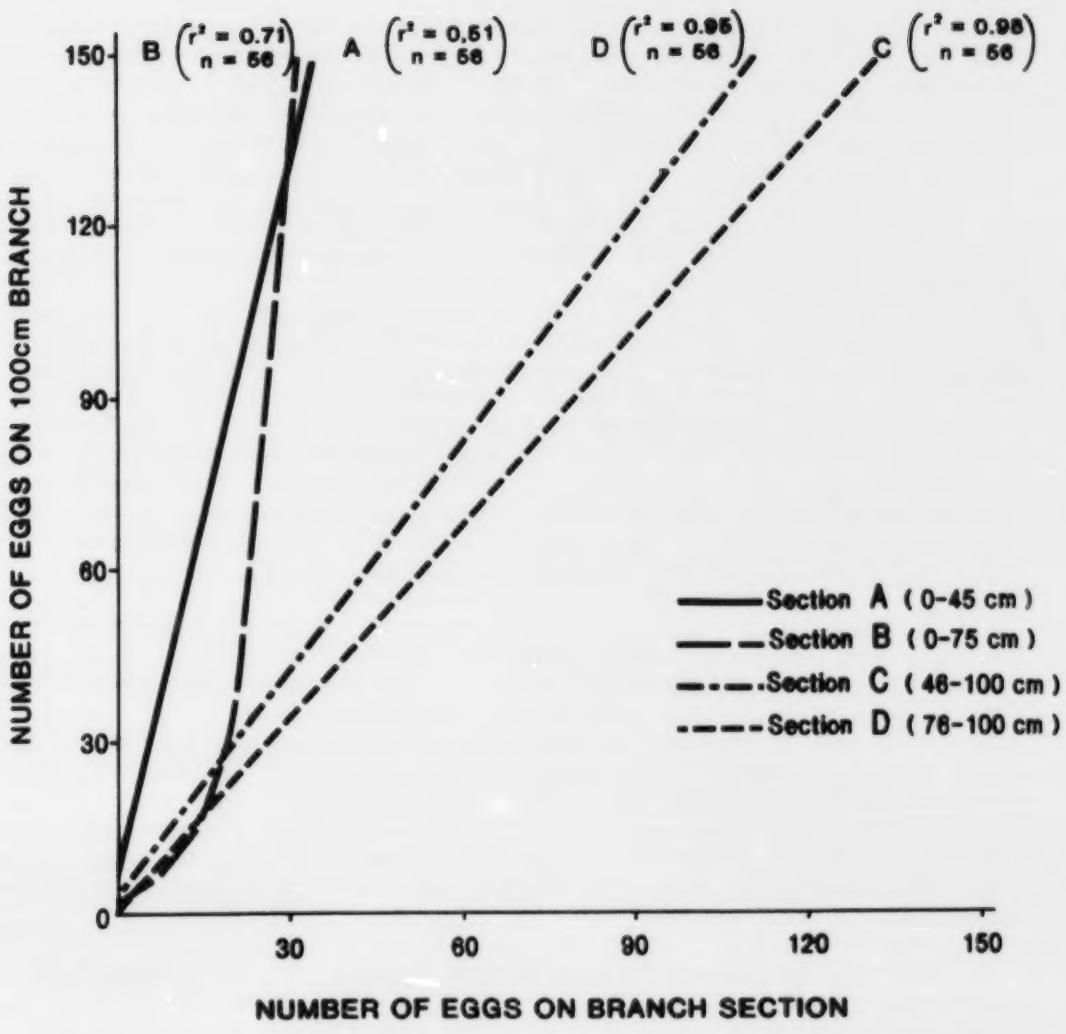


Figure 4. Regressions of hemlock looper egg counts per 100-cm branch vs sub-sections of the 100-cm branch.

4.3 Egg Counts as a Predictor of Defoliation by Hemlock Looper

In 1990, the very first hemlock looper protection program was conducted in New Brunswick (Hartling and Carter , 1991). The concern for possible tree mortality, based on experiences in other jurisdictions, and observed severe feeding damage at several New Brunswick plots in 1989, combined with the tight provincial wood supply situation, convinced DNRE officials to spray the entire outbreak. Based on this decision, all plots in northern New Brunswick averaging 10 to 90 eggs per branch in 1989 were treated with insecticide. The only unsprayed plots which existed to compare defoliation to populations of fewer than 10 eggs per branch occurred in the southwestern part of the province where populations were regarded too low for treatment.

Hemlock looper larvae upon hatching feed on new foliage produced that growing season. In later instars, the insects switch feeding preference to older growth foliage (Martineau, 1984). This pattern of feeding behavior makes it necessary to evaluate damage by (1) assessing defoliation of current year's foliage, and (2) assessing defoliation of all age classess of foliage (both old and current) before and after larval feeding.

Based on data from 35 fir plots sampled in the fall of 1989, it was found that counts up to 9 eggs per 100-cm branch per plot yielded less than 10% needle loss of current year's foliage and less than 17% needle loss for all foliage age classes combined.

4.4 Egg Survey as a Predictor of Larval Populations

Although all plots having ten or more eggs per 100-cm branch were treated with insecticide in 1990, there were 38 plots where larval counts were made after larval hatch and prior to spraying. At the time of sampling the larval index[1] ranged from 1.2 to 2.9. An attempt was made to cut 45-cm branches from the mid-crown of selected trees; in reality branch lengths ranged from 34 to 91 cm. When the branch was cut and dropped to a tarpaulin, many larvae were disloged, therefore the entire branch had to be included as the sample unit. Cut branches which hit other branches in falling were discarded and another sample taken. Larval counts were standardized by area and unit branch length, then compared to egg counts of the previous fall.

Regression lines of larval counts versus egg counts were calculated for the data set (Figure 5). The r^2 values were 0.76 and 0.72 where larval counts were expressed per square metre of foliage and per 100-cm branch length, respectively. This indicates that egg counts are a good predictor of spring larval populations.

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1. Larval Index = [(No. L1) x 1 + (No. L2) x 2 ... + (No. L5) x 5] ÷ Total No. Larvae.

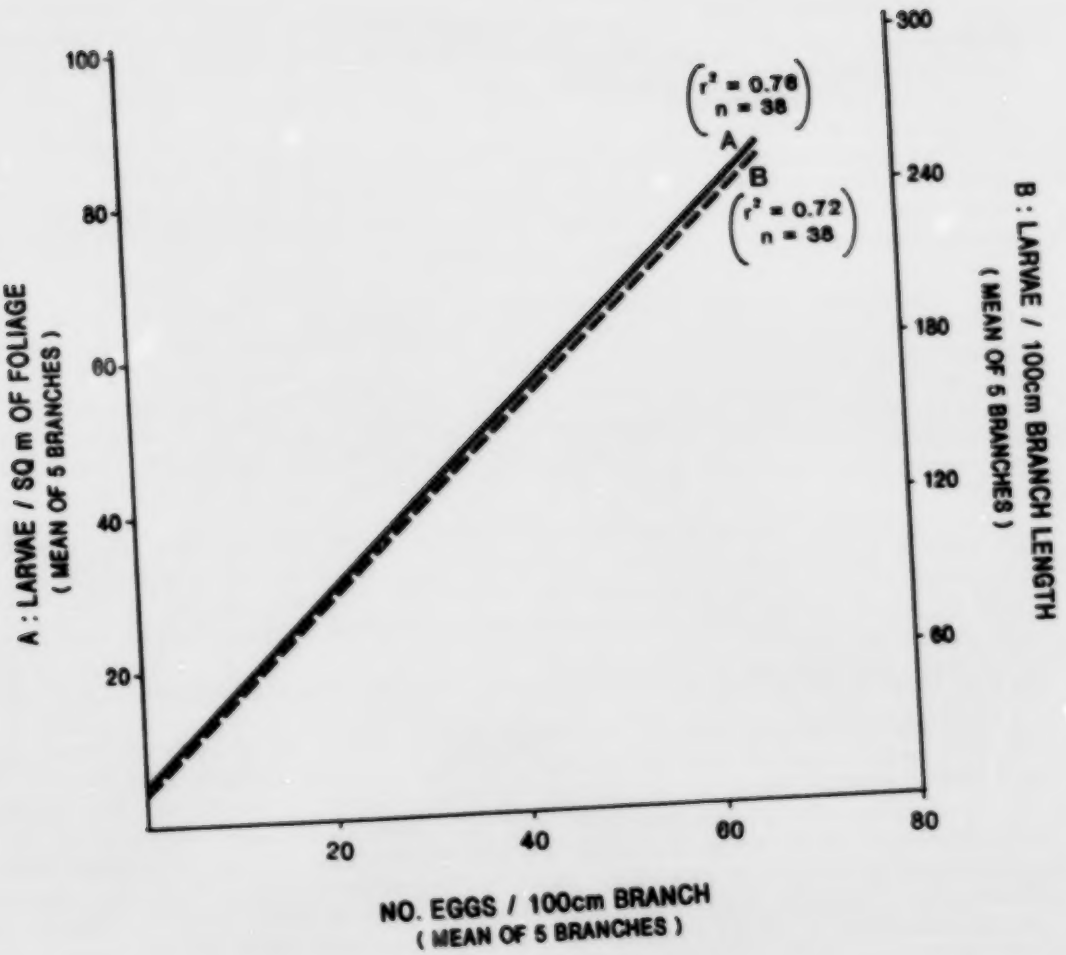

Figure 5. Regressions of fall egg counts vs subsequent spring larval counts (L1-L3).

SUMMARY

The hemlock looper outbreak in northern New Brunswick in 1989 was the first outbreak detected in the province. The previous lack of economic importance of the hemlock looper in New Brunswick meant that no significant local research had been conducted on this pest. Prior to the current outbreak, published data specific to New Brunswick was limited to general biological information and population counts from routine insect monitoring programs. This report summarizes more specific and detailed information collected by DNRE in 1989 and 1990 on looper larval development, pupal and egg parasites, and forecast survey methods.

This report describes for the first time, to the best of the authors' knowledge, that five larval instars occur in New Brunswick. Information is presented on head capsule measurements, color, and marking characteristics; and the relationship between larval development and degree-day accumulations is provided.

Parasitic wasps and tachinid flies accounted for pupal parasitism rates of 19% and 16% in 1989 and 1990, respectively. No attempt was made to investigate larval parasitism or diseases.

Egg parasitism was negligible in 1989. It was higher in 1990, with 21% of the plots having levels of parasitism ranging from 1-5% to 91-100%. Much of the parasitism was due to an undentified parasite already emerged from the looper eggs at the time of sampling. Other parasites reared from looper eggs were Trichogramma minutum Riley and Trichogramma sp.

Egg survey methodology for forecasting was examined to determine the appropriate number of balsam fir trees to sample, and the distribution of eggs within a 100-cm branch cut from the lower crown. Three trees were found to be as representative as five or ten trees. The feasibility of only processing the basal 46 to 100-cm subsection of a 100-cm branch is suggested.

The egg survey was found to be a good predictor of spring larval populations but data on the relationship between egg counts and defoliation were limited. Mean counts of 10 or more eggs per 100-cm branch were unavailable to compare with defoliation as plots having mean counts of 10-90 eggs per branch were treated with insecticide. More data are needed in unsprayed areas to enable derivation of forecast curves.

Information presented in this report should be of value to researchers as well as foresters and entomologists responsible for conducting "operational" hemlock looper surveys and control programs. Nevertheless, this information should not be considered as "definitive", but rather as the first step in researching hemlock looper in the Province. Much more research is needed, especially if this insect becomes a more wide-spread pest within the next few years.

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APPENDIX A

Study Locations
Reported in Text.

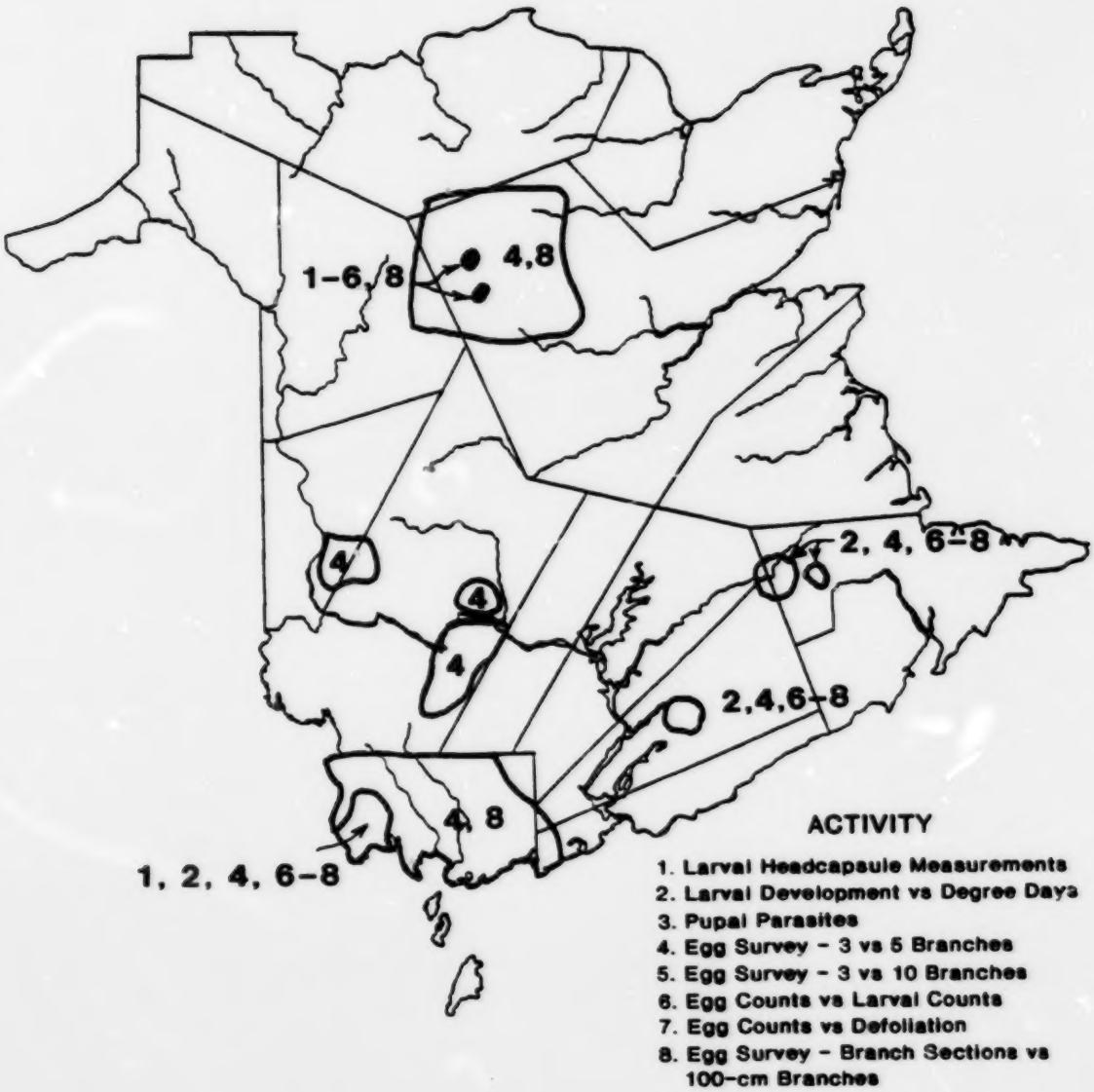

Figure A-1. Locations where hemlock looper was sampled in 1989-90.

APPENDIX B

Hemlock looper egg extraction process as used in New Brunswick.[1]

1. from Hartling and Carter (1991)

STEPS IN HEMLOCK LOOPER EGG EXTRACTION PROCESS AS USED IN NEW BRUNSWICK

(1) At the start of each day, 200 ml of Javex bleach (6% sodium hypochlorite) and 9.8 litres of cold tap water are put in each 14-litre pail to be used for the wash. Thus, a 2% solution of Javex is used.

(2) Each branch, 100-cm long, is cut into 8-cm pieces and placed in the Javex solution.

(3) The branches are lightly stirred every 15 minutes. After 45 minutes in the solution, the rinsing process begins.

(4) The javex solution is retained and recycled within one day by pouring it from the 14-litre pail, through a 3-sieve system into a 23-litre pail. The top sieve 850 micron (#20) catches the branch; the middle sieve, 425 micron (#40) catches some of the larger particles of dirt and the hemlock looper eggs; and the bottom sieve, 212 micron (#70), catches finer particles of dirt that go through the other two sieves. Material on this sieve is discarded. This makes the recycled solution much cleaner. Note, this is the only use of the number 70 sieve as all the eggs are caught in the number 40 sieve.

(5) The two other sieves are placed in the wash sink, with the number 20 sieve on top of the number 40 sieve. The branch is lightly sprayed with water and the hemlock looper eggs as well as particles of dirt and lichen are rinsed through the number 20 sieve into the number 40 sieve.

(6) The branch is then re-immersed in a bucket of water (= double rinse) and then poured over the number 20 and 40 sieves; the branch is lightly sprayed with water as described in the previous step.[1]

(7) Everything on the number 40 sieve is then rinsed down and funnelled into a mason jar.

(8) The contents, or a portion of the contents of the mason jar are poured into a Buckner funnel lined with grided filter paper. Numerous filter papers are used per jar, to avoid the eggs being buried under dirt particles. Therefore the amount of dirt per sample dictates the number of filter papers used per sample.

(9) Using a dissecting microscope (6.4x magnification) the hemlock looper eggs are identified and the number of eggs/branch sample is recorded.

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1. The double rinse procedure was implemented in the fall of 1990, after testing revealed that an average 16% of the total eggs were not dislodged in the first rinse. (The double rinse had not been used in processing foliage samples collected during the fall and winter egg survey of 1989/90).